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ELECTRON WORK FUNCTIONS OF THE ELEMENTS

Compiled by Herbert B. Michaelson, 1977

The measured values cited for polycrystalline and single-crystal specimens are selected as being the best available data at this time. The selection is based on (1) The validity of the experimental technique (e.g., vacua of 10^{-9} or 10^{-10} Torr, clean surfaces, and identification of crystal-face distribution and other surface conditions), and (2) Best agreement with preferred values and theoretical values of the true work function (given variously by Fomenko,[1] Rivière,[2] Trasatti,[3] and Lang and Kohn[4]). Experimental data that are not well substantiated according to these criteria are listed in *italics*. Crystallographic directions for single-crystal data are indicated by parentheses.

Abbreviations apply to the experimental method: T, thermionic; P, photoelectric; CPD, contact potential difference; F, field emission. Important distinctions among such measurements are discussed in the Rivière[2] paper, pp. 180 to 198.

Element	Experimental value, ϕ (eV)	Experimental method	Ref.	Element	Experimental value, ϕ (eV)	Experimental method	Ref.
Ag	*4.26*	P	5	Hg	4.49	P	27
	4.64 (100)	P	5	In	4.12	P	28
	4.52 (110)	P	5	Ir	*5.27*	T	29
	4.74 (111)	P	6		5.42 (110)	F	30
Al	4.28	P	7		5.76 (111)	F	30
	4.41 (100)	P	8		5.67 (100)	F	31
	4.06 (110)	P	7		5.00 (210)	F	31
	4.24 (111)	P	8	K	2.30	P	32
As	*3.75*	P	9	La	3.5	P	10
Au	5.1	P	10	Li	2.9	F	33
	5.47 (100)	P	11	Lu	*3.31*	CPD	34
	5.37 (110)		11	Mg	*3.66*	P	35
	5.31 (111)		11	Mn	4.1	P	10
B	*4.45*	T	12	Mo	4.6	P	10
Ba	*2.7*	T	13		4.53 (100)	P	36
Be	4.98	P	14		4.95 (110)	P	36
Bi	*4.22*	P	15		4.55 (111)	P	36
C	*5.0*	CPD	16		4.36 (112)	P	36
Ca	2.87	P	17		4.50 (114)	P	36
Cd	*4.22*	CPD	18		4.55 (332)	P	36
Ce	2.9	P	10	Na	2.75	P	37
Co	5.0	P	10	Nb	4.3	P	10
Cr	4.5	P	10		4.02 (001)	T	38
Cs	2.14	P	19		4.87 (110)	T	38
Cu	4.65	P	10		4.36 (111)	T	38
	4.59 (100)	P	20		4.63 (112)	T	38
	4.48 (110)	P	20		4.29 (113)	T	38
	4.94 (111)	P	20		3.95 (116)	T	38
	4.53 (112)	P	20		4.18 (310)	T	38
Eu	2.5	P	10	Nd	3.2	P	10
Fe	4.5	P	10	Ni	5.15	P	10
	4.67 (100)	P	21		5.22 (100)	P	39
	4.81α (111)	P	22		5.04 (110)	P	39
	4.70α	P	23		5.35 (111)	P	39
	4.62β	P	23	Os	*4.83*	T	29
	4.68γ	P	23	Pb	4.25	P	40
Ga	4.2	CPD	24	Pd	5.12	P	31
Ge	5.0	CPD	25		5.6 (111)	P	41
	4.80 (111)	P	26	Pt	5.65	P	10
Gd	3.1	P	10		5.7 (111)	P	41
Hf	3.9	P	10	Rb	*2.16*	P	27

ELECTRON WORK FUNCTIONS OF THE ELEMENTS (continued)

Element	Experimental value, φ (eV)	Experimental method	Ref.
Re	*4.96*	T	29
	5.75 (1011)	F	33
Rh	4.98	P	31
Ru	4.71	P	31
Sb	4.55 (amorph.)	–	42
	4.7 (100)	–	43
Sc	3.5	P	10
Se	5.9	P	44
Si	4.85n	CPD	40
	*4.91*p (100)	CPD	45
	4.60p (111)	P	46
Sm	2.7	P	10
Sn	*4.42*	CPD	47
Sr	*2.59*	T	48
Ta	4.25	T	29
	4.15 (100)	T	49
	4.80 (110)	T	49
	4.00 (111)	T	49
Tb	3.0	P	50
Te	4.95	P	44
Th	3.4	T	51
Ti	4.33	P	10
Tl	*3.84*	CPD	52
U	3.63	P & CPD	53
	3.73 (100)	P & CPD	54
	3.90 (110)	P & CPD	54
	3.67 (113)	P & CPD	54
V	4.3	P	10
W	4.55	CPD	55
	4.63 (100)	F	30
	5.25 (110)	F	30
	4.47 (111)	F	30
	4.18 (113)	CPD	56
	4.30 (116)	T	57
Y	3.1	P	10
Zn	*4.33*	P	15
	4.9 (0001)	CPD	58
Zr	4.05	P	10

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PROPERTIES OF METALS AS CONDUCTORS

Metal.	Resistivity microhm-centimeters 20° C	Temp. coefficient 20° C.	Specific gravity.	Tensile strength, lbs./in.	Melting point ° C.
*Advance. See *constantan*					
Aluminum	2.824	0.0039	2.70	30,000	659
Antimony	41.7	.0036	6.6	....	630
Arsenic	33.3	.0042	5.73	....	....
Bismuth	120	.004	9.8	....	271
Brass	7	.002	8.6	70,000	900
Cadmium	7.6	.0038	8.6	....	321
*Calido. See *nichrome*					
Climax	87	.0007	8.1	150,000	1250
Cobalt	9.8	.0033	8.71	....	1480
Constantan	49	.00001	8.9	120,000	1190
Copper: annealed	1.7241	.00393	8.89	30,000	1083
hard-drawn	1.771	.00382	8.89	60,000	....
Eureka. See *constantan*					
Excello	92	.00016	8.9	95,000	1500
Gas Carbon	5000	−.0005	....	....	3500
German silver, 18% Ni	33	.0004	8.4	150,000	1100
Gold	2.44	.0034	19.3	20,000	1063
Ideal. See *constantan*					
Iron, 99.98% pure	10	.005	7.8	....	1530
Lead	22	.0039	11.4	3,000	327
Magnesium	4.6	.004	1.74	33,000	651
Manganin	44	.00001	8.4	150,000	910
Mercury	95.783	.00089	13.546	0	−38.9
Molybdenum, drawn	5.7	.004	9.0	....	2500
Monel metal	42	.0020	8.9	160,000	1300
*Nichrome	100	.0004	8.2	150,000	1500
Nickel	7.8	.006	8.9	120,000	1452
Palladium	11	.0033	12.2	39,000	1550
Phosphor bronze	7.8	.0018	8.9	25,000	750
Platinum	10	.003	21.4	50,000	1755
Silver	1.59	.0038	10.5	42,000	960
Steel, E. B. B	10.4	.005	7.7	53,000	1510
Steel, B. B	11.9	.004	7.7	58,000	1510
Steel, Siemens-Martin	18	.003	7.7	100,000	1510
Steel, manganese	70	.001	7.5	230,000	1260
Tantalum	15.5	.0031	16.6	....	2850
*Therlo	47	.00001	8.2	....	....
Tin	11.5	.0042	7.3	4,000	232
Tungsten, drawn	5.6	.0045	19	500,000	3400
Zinc	5.8	.0037	7.1	10,000	419

* Trade mark.

Superconductivity*

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The following tables on superconductivity include superconductive properties of chemical elements, thin films, a selected list of compounds and alloys, and high-magnetic-field superconductors.

The historically first observed and most distinctive property of a superconductive body is the near total loss of resistance at a critical temperature (T_c) that is characteristic of each material. Figure 1(a) below illustrates schematically two types of possible transitions. The sharp vertical discontinuity in resistance is indicative of that found for a single crystal of a very pure element or one of a few well annealed alloy compositions. The broad transition, illustrated by broken lines, suggests the transition shape seen for materials that are not homogeneous and contain unusual strain distributions. Careful testing of the resistivity limits for superconductors shows that it is less than 4×10^{-23} ohm-cm, while the lowest resistivity observed in metals is of the order of 10^{-13} ohm-cm. If one compares the resistivity of a superconductive body to that of copper at room temperature, the superconductive body is at least 10^{17} times less resistive.

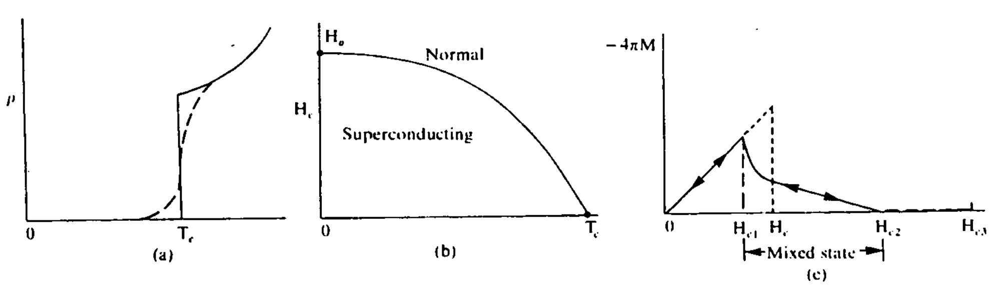

Figure 1. PHYSICAL PROPERTIES OF SUPERCONDUCTORS

(a) Resistivity versus temperature for a pure and perfect lattice (solid line). Impure and/or imperfect lattice (broken line).
(b) Magnetic-field temperature dependence for Type-I or "soft" superconductors.
(c) Schematic magnetization curve for "hard" or Type-II superconductors.

The temperature interval ΔT_c, over which the transition between the normal and superconductive states takes place, may be of the order of as little as 2×10^{-5} K *or* several °K in width, depending on the material state. The narrow transition width was attained in 99.9999 percent pure gallium single crystals.

*Prepared for Office of Standard Reference Data, National Bureau of Standards, by Standard Reference Data Center on Superconductive Materials, Schenectady, N.Y.